April 30, 2008

Strengthening x-ray detector development and support efforts at the APS

Summary

This proposal is designed to strengthen the detector effort at the APS, resulting in short- and medium-term impact on the scientific productivity of APS beamlines and positioning the facility for long-term growth in the area of x-ray detector development. We request 3 new FTEs, $710K M&S, and $400K capital equipment funds over 5 years to: 1. strengthen and expand the BTS group detector development effort; and 2. expand test and modeling facilities for detector characterization. We assume that capital equipment funding for the APS Detector Pool will continue at the present average rate of $400K/year.

Impact on Science at the APS

1. Strengthen and expand the XSD-BTS group detector development effort: 3 new FTEs; $650K M&S over 5 years.

Since 2003, the APS has undertaken the establishment of a detector integration and development effort in the XSD Beamline Technical Support group. This effort has been very successful in building detectors around existing sensors, e.g. custom RF electronics and packaging for avalanche photodiode detectors for several APS beamlines, and a four-element, high sensitivity small angle scattering CCD camera for sector 12. The group is also involved in collaborative projects with the Advanced Light Source on multiple-readout CCD detectors and with Argonne MSD and CNM personnel in high resolution (few eV) spectroscopy x-ray detectors based on superconducting transition edge sensors (TES).

While XSD-BTS has been successful in these detector projects, it has become obvious that developing cutting-edge detectors requires expertise in application specific integrated circuit (ASIC) design and in semiconductor device (sensor) physics. We propose to add two new FTEs with expertise in these areas to the XSD-BTS group. The added expertise will enable us to tackle the development of custom detectors for inelastic scattering (e.g. germanium strip detectors), radiography (analog pixel array detectors), fluorescence detection (custom geometry, fast, large solid angle detector arrays), and other areas that are currently "green fields," such as picosecond timing detectors and few-eV resolution detectors efficient at high energies (> 50 keV). The new projects will be conducted while continuing to grow in the area of detector integration, which includes analog printed circuit board electronics, digital on-board data reduction acquisition systems, and electro-mechanical design and manufacture. We also request a third FTE (electronics technician) to continue to support and grow our detector integration and development efforts.

2. Expand test and modeling facilities for detector characterization: $400K capital equipment funds over 3 years; $60K M&S over 2 years

Fully instrumented optical and x-ray test facilities, plus associated modeling tools, will allow detailed characterization, benchmarking, and troubleshooting of detectors owned by APS beamline personnel and users, detectors developed by our group, and the inventory in the APS Detector Pool, as well as equipment obtained from commercial vendors for evaluation and prototypes developed by our industrial collaborators under Small Business Innovation Research (SBIR) program grants. The expected impact on APS science is enhanced productivity due to: additional capability to design custom detectors using our modeling tools; reduced downtime due to detector malfunction (ease of diagnosis; ability to periodically test equipment to identify failure trends; better QA for detectors developed by our group); and ability to prototype novel electronics and detector concepts (gigahertz testing of ultra-fast electronics; cryogenic testing of semiconductor materials; milli-Kelvin test stand for TES-based spectroscopy detectors).

The funds requested will be used to complete our optical test stand in 401-L3120 (currently 80% complete); to complete and add cryogenic capabilities to our x-ray test stand in 401-L0111; to purchase gigahertz test equipment; and to develop QA capabilities (e.g. "shake and bake") for detector components. Completion of these test facilities will also include the purchase or development of modeling capabilities to understand detector response from the sensor to the output data.

Added value of the medium term upgrade

The purpose of this proposal is two-fold: to support detector operations and development at the APS in the short and medium term; and to further extend the capabilities of the BTS group in the area of cutting-edge x-ray detector R&D.

Our proposal will allow us to support and implement several detector projects being put forward by the APS user community as part of their medium term beamline upgrade plans, while continuing work on existing projects. Examples of medium term detector proposals include the development of germanium strip detectors for sectors 9 and 30; large solid angle, fast response fluorescence arrays proposed by sectors 2, 4, 11, 20, and 26; and analog silicon pixel array detectors for sectors 7 and 15. Our group would pursue these projects through a combination of approaches, including collaborations with universities, national laboratories, and other light sources; collaborations with industry, e.g. via SBIR grants; supporting commercial acquisitions, e.g. working with vendors in the development of cutting-edge commercial detectors; and in-house development and integration.

The addition of two FTEs with skills in device physics and ASIC design will position our group to expand in forward-thinking detector R&D. The aim is conduct research to identify the next breakthrough detector technology, while at the same time satisfying current detector demands. While important for the success of planned medium term upgrades, the capability to be at the forefront of detector R&D is indispensable for the complete success of any long term APS upgrade. For example, we should try to answer the following questions: Are there better materials than germanium and gallium arsenide for detecting high energy (> 50-100 keV)

x-rays? Do current and future semiconductor technologies allow for the high bandwidths required for picosecond detectors? The added expertise in theory, design, and prototyping will also allows us to collaborate even more effectively with other national and international players in the field and to establish a solid detector R&D program at the APS. The addition of an electronics technician will allow us to more efficiently execute current and planned detector projects

Enhancements to our test stands also support detector operations and development related to beamline upgrades by providing characterization, prototyping, and modeling facilities for existing and new detectors, commercial or one-of-a-kind.

Expected user community

Our group has developed or is currently developing detectors and supporting data acquisition electronics for 12-ID (SAXS camera); 7-ID, 8-ID, 20-ID (APD detectors, both single elements and arrays of single elements); and 8-ID (quasi-column-parallel, fast CCD detectors (in collaboration with the ALS) and on-board correlators for XPCS data reduction). We are also exploring the development of TES for very high-energy-resolution applications at sectors 1, 2, 13, and 20, and pursuing the development of silicon array detectors with industry (via the company's on-going SBIR phase 2 grant) for sectors 7,8,11,13 and 20.

We expect that an enhanced detector program at the APS will be able to provide services to an even larger fraction of XOR and non-XOR beamlines. As mentioned above, the resources requested in this proposal will support the detector component of proposed medium term upgrades at sectors 2, 4, 7, 9, 11, 15, 20, 26, and 30.

The expanded detector test stands and modeling capabilities will continue to be made available to the APS community. Our optical test stand is 80% complete and has already seen heavy use by beamline personnel from sectors 2 and 32, being used primarily to characterize CCD cameras and optical trains.

Enabling technology and infrastructure

Key component of this proposal are:

- Identifying and hiring 3 additional FTEs with skill sets complementary to our existing resources.
- Obtaining sufficient M&S funds to carry out R&D work in sensor and ASIC design and prototyping.
- Enhancing the capabilities of our test stands to allow cryogenic operations, crucial for R&D in novel sensor materials and TES-based detectors. Developing extensive source-to-data modeling capabilities.

Partnerships and user interest

As described above, we plan to support detector and data reduction related aspects of medium term upgrade efforts at sectors 2, 4, 7, 9, 11, 15, 20, 26, and 30. We assume that, if approved and funded, the individual projects will provide the necessary capital equipment and M&S monies to pursue the associated detector development.

We also plan to continue existing collaborations on detector development with the P. Denes and H. Padmore (ALS) and V. Novosad (MSD), and to explore new collaborations with S. Gruner (CHESS) and other national laboratories and universities as appropriate. We expect that we will also establish a close partnership with the ASIC design group at Fermi National Laboratory.

We plan to continue close collaborations with university-level integrated circuit fabrication facilities, including our now 3-year on-going work with Northern Illinois University. These types of collaborations will provide such benefits as access to IC design software tools, ability to tap academic experience and student help, and will provide a low cost work area, clean room space, to explore IC fabrication and device physics. We will also seek to expand our efforts through collaborations with the Center for Nanoscale Materials.

Industry and technology transfer

When appropriate, we plan to partner with industry in our research and development efforts. Currently this often takes the form of working under the auspices of the DOE Small Business Innovation Research grants program. We work with industry to specify detectors useful to our x-ray science community, and to test and evaluate the intermediate and final detector products. In this way we can tap our industrial partners' vast technical expertise while at the same time contribute in areas where we have excellent facilities and extensive experience.

Estimated budget

	Year 1	Year 2	Year 3	Year 4	Year 5	**Total**
FTE	2	1				**3**
M&S - $K	160	160	130	130	130	**710**
Capital - $K	200	100	100			**400**
Total $K	**360**	**260**	**230**	**130**	**130**	